CASE STUDY NO. 10

Cottages at Cypress

PHOTO: RYAN FILGAS

Cottages at Cypress

Case Study No. 10

Data Summary

Building Type: Multifamily – Low Income Senior Housing (New Construction)

Location: Fort Bragg, CA

Gross Floor Area: 17,260 gross sq. ft.

Occupied: 2014

On-Site Renewable Energy System Installed:
131 kW (DC) Solar PV – total
1BR unit: 4 kW (DC)
2BR unit: 5 kW (DC)
Communal Bldgs: 20 kW(DC)

On-Site Storage Battery: None

Measured On-Site Energy Production:
1BR unit (#26):
39.9 kBtu/sq.ft. per year
2BR unit (#23):
31.5 kBtu/sq.ft. per year

Modeled EUI (Site):
1BR unit:
27.8 kBtu/sq.ft. per year
2BR unit:
24.3 kBtu/sq.ft. per year

Measured EUI (Site):
1BR unit (#26):
17.4 kBtu/sq.ft. per year
2BR unit (#23):
13.9 kBtu/sq.ft. per year

Owner/Client
Danco Group, Arcata, CA

Project Team

Architect:
K.Boodjeh Architects, Eureka, CA

Structural Engineer:
Branch Engineering, Inc., Springfield, OR

Energy and Sustainability Consultant:
Redwood Energy, Arcata, CA

Solar PV System Design & Installation:
Roger, Arcata, CA

General Contractor:
Danco Builders Northwest, Arcata, CA

"Affordable housing" is a recognized urgency for many subsets of the population, each with its special needs and aspects. For some, this subset is low-income families or the homeless with support service needs, as in two previous case study projects in this series of books, *Zero Net Energy Case Study Homes*. This case study is yet another group for which affordable housing has become an urgent issue: low-income seniors.

What is common to all housing currently under development for these populations is the desirable aspect of zero-net-energy (ZNE) performance for the completed project for the simple reason that future energy costs for the tenant or building operator are *zero*. Indeed, the award of the contract for the design and construction of an affordable housing project often depends on this feature being included in the proposal. The financing arrangements for the project are structured so that ZNE is a natural method of keeping future operating costs low and predictable.

The form of the building program and project design are also quite different, depending on the social group and location. The ZNE design strategies are therefore different as well. This case study, a project for low-income seniors in a semi-rural area, is a case in point. In a location on the California coast where the decline in fishing and timber industries has led to a decline in moderate incomes, seniors now comprise most of the low-income population. Their lifelong familiarity with and preference for individual homes rather than larger complexes of adjacent units led to the concept of the neighborhood of small houses, or individual "cottages". The ZNE design strategies therefore involve smaller independent systems and envelope-dominated design of small buildings rather than other types of design approaches better suited to larger buildings.

Background

The initiator of this project, Danco Group, is an affordable housing, for-profit developer that was looking to initiate a project in the Fort Bragg area on the Northern California coast. Affordable housing for seniors in one of a portfolio of types of affordable housing pursued by Danco Group in addition to low-income family and supportive-services types. Most of their projects are initiated by the company rather than packaged in response to a specific RFP. The company has a construction division and a property management division, which are involved in their projects at various times.

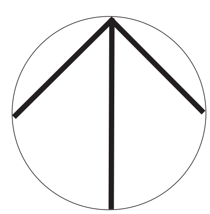
Their methodology is that they proactively seek such projects in their geographic area, Northern California between San Francisco and the Oregon border, and the company puts together proposal packages to interest local governments who want to create them for their constituents. If there is interest, Danco Group forms a limited partnership for the project, arranges the financial packages and then acts as the design-build entity to construct the final product. There is a nonprofit partner within that limited partnership (LLC) that is the "managing general partner", while Dance Group is the "administrative general partner". A limited partner to provide financing and to buy the tax credits is the third member of the LLC.

Danco Group chose the City of Fort Bragg as a good candidate for their strategic plan to develop affordable housing and approached the city with a proposal for a project for low-income seniors, the local population with the highest need for this type of housing. The city accepted the idea. The company sought and received federal tax credits for the project through a program of the U.S. Department of Agriculture (USDA), which had a requirement at the time that funding required that the project be ZNE. Thus, ZNE was integral to the program, as described above.

> "It does not cost an affordable housing project any more money to go net zero"
> —Chris Dart, President of Danco Group.

The project site was found after three years of searching and Danco Group, upon final agreement with the city, purchased the land and began the project.

Cottages at Cypress - General Vicinity Plan



(Opposite page) Site Plan for The Cottages at Cypress.

(Left) View of the project from Cypress Street. (Photo by Ryan Filgas.)

Project Process

Building Program

The program reflects the strong desire of the target population to continue living in separate homes as they have been doing throughout their lives while raising families and working in the local industries. They were not inclined to be forced to live in the close quarters of the unfamiliar housing type of an apartment building or other clusters of units. The developer therefore elected to build small individual homes of the type that were familiar to most local people.

As planned and built, the project consists of eighteen (18) one-bedroom cottages, six (6) two-bedroom cottages and one manager's cottage, for a total of 25 small houses on the two-acre site. There are also two communal buildings: the community center and the shared laundry facility.

The cottages are quite small: between 550 sq. ft. and 582 sq. ft. for the one-bedroom units and between 782 sq. ft. and 821 sq. ft. in the two-bedroom units. The shared community building, with the large open room for meetings, a kitchen and a manager's office, is 1200 sq. ft. The separate common laundry facility is 470 sq. ft. All the buildings total 17,260 sq. ft.

The site includes a designated "coastal wetland area" that was to be enhanced and restored as part of the development. This included a significant portion of the southwest corner of the site. (See the landscape site plan on the opposite page.)

The project was also programmed as an all-electric development in order to keep the carbon footprint minimal.

Site Constraints

Large cypress trees at the northeast corner of the site cast a significant amount of shade on that corner of the site. Because of the limited size of the site and the number of houses planned, units would have to be located in that shaded area.

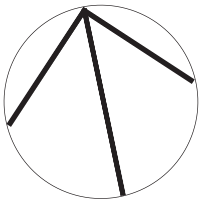
Solar shade analysis showed that two of the house building sites would be negatively affected, namely units #8 and #12. (See the site plan on page xx.) The solar PV systems planned for those units would not be productive, so their PV panels were placed elsewhere on the site where sunlight exposure was good, namely on the roof of the communal buildings. (See the discussion below in *Renewable On-Site Energy Supply*.)

Low Energy Design Strategies

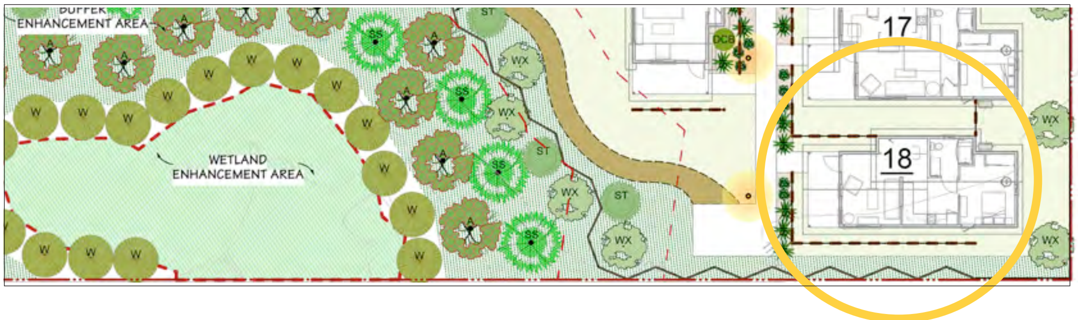
As with the affordable housing Case Study No. 9, the Silver Star Apartments, ZNE performance was part of the program brief, so the solar PV systems were sized to cover slightly more than the annual energy demand of the houses, in this case 110%. The one-bedroom units have very similar floor plans and orientations, so this energy demand is much the same for each unit of this type and the same system could be specified for each one. The same is true for the two-bedroom units.

Many of the house plans are repeated for both the one-bedroom and two-bedroom units, but are rotated in orientation to make the site plan work. Since the solar panels must face south, this resulted in a different roof orientation and design for the same floor plan.

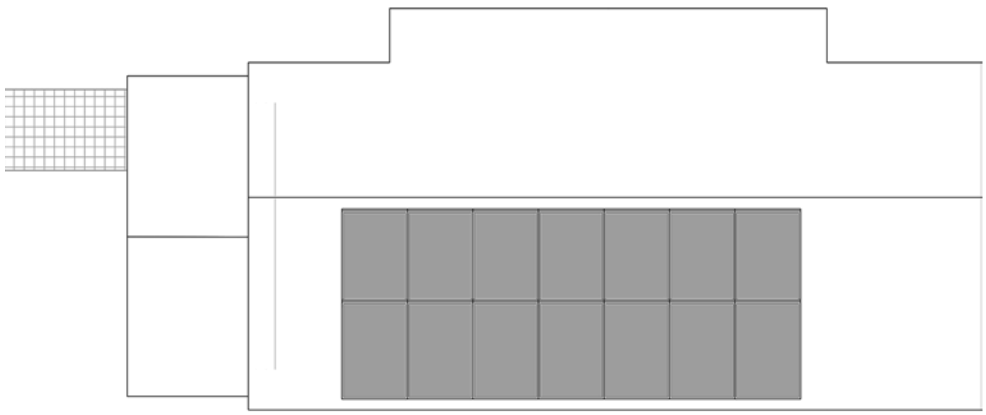

CYPRESS STREET
SHORTER PLANTINGS FOR SAFE VISIBILITY AT DRIVEWAY
4 A1.7 ENTRY SIGN
(E) SIDEWALK
WALKWAY BOLLARD LIGHT, CFL LAMP, DARK-SKY COMPLIANT, REFER TO ELECTRICAL, TYP.
RECYCLED PLASTIC BENDER BOARD AT ALL LAWN TO MULCH TRANSITIONS, TYP.
TALLER PLANTINGS SCREEN PARKING & BACKFLOW PREVENTER
ALL HEAT PUMP UNITS AND UTILITIES ARE LOCATED OUT OF VIEW AND/OR SCREENED BY LANDSCAPING
OPEN GRADED PERMEABLE PAVING, REFER TO SITE GRADING & DRAINAGE PLAN
16 A1.6 HYDROSEED LAWN @ GRASSPAVE2 PARKING STALLS
GRASS SWALE
BRIDGE
1 A1.7
7 A1.6 AGGREGATE PATH
AGGREGATE PATH
LAWN
3 A1.7 SPLIT RAIL FENCE
LED POLE LIGHT, 20 FT TALL, DARK SKY COMPLIANT, REFER TO ELECTRICAL, TYP.
EXT. LIGHTS ATTACHED TO BUILDINGS ARE NOT SHOWN HERE, SEE BLDG ELECTRICAL PLANS, TYP.
WOOD FENCE 6 FT TALL. INSTALL MAN GATE(S) AS REQUIRED BY FORT BRAGG FIRE DEPT.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
NATURE TRAIL INTERPRETIVE SIGN
50 FT BUFFER
30 FT BUFFER
BUFFER ENHANCEMENT AREA
WETLAND ENHANCEMENT AREA



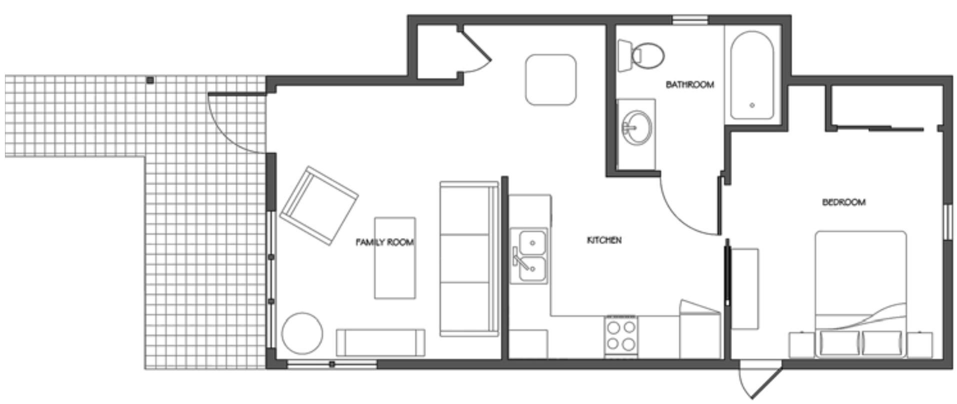
NORTH



COTTAGE #18
1 BR UNIT

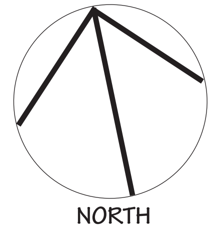


ROOF PLAN

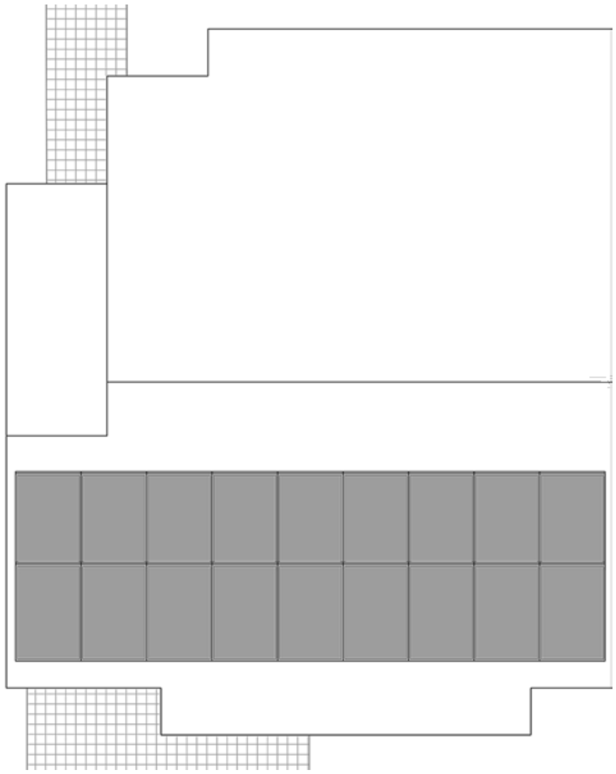


COTTAGES AT CYPRESS — FLOOR PLANS AND SECTIONS

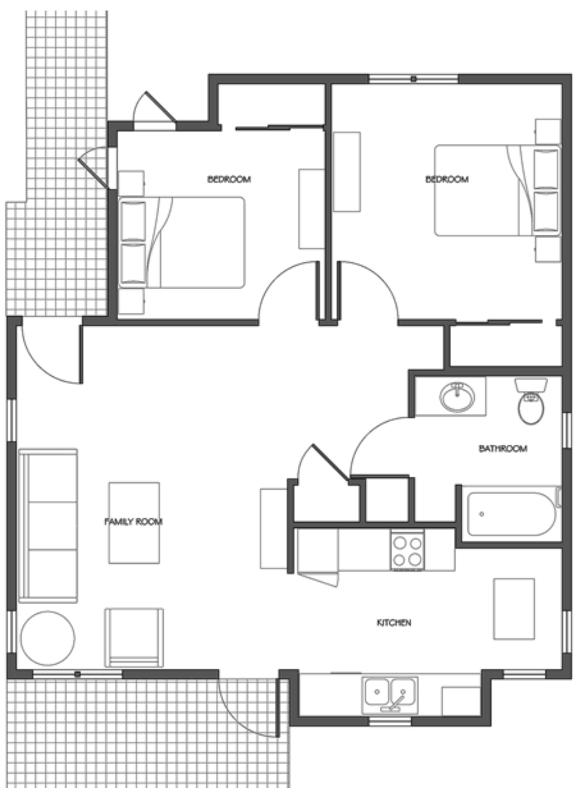
FLOOR PLAN



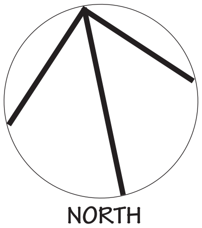
COTTAGE #23
2 BR UNIT

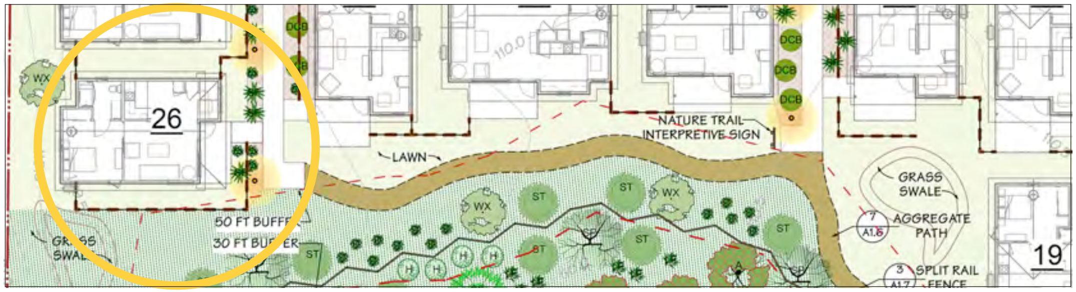


ROOF PLAN

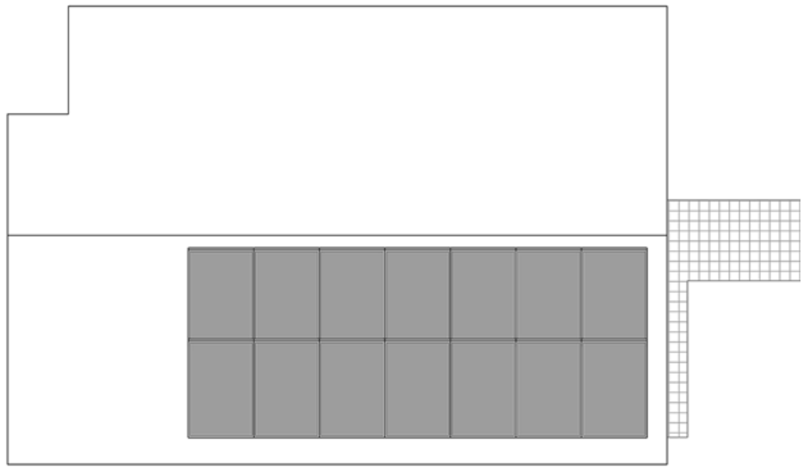


FLOOR PLAN

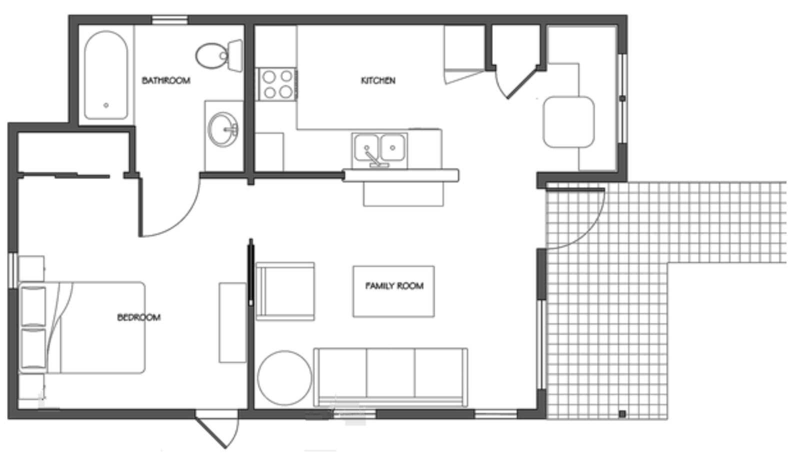




COTTAGE #26
1 BR UNIT



ROOF PLAN

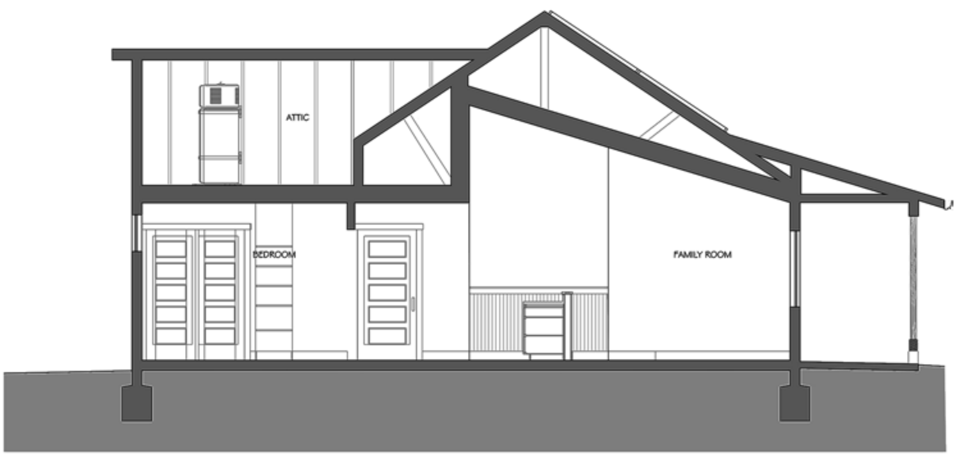


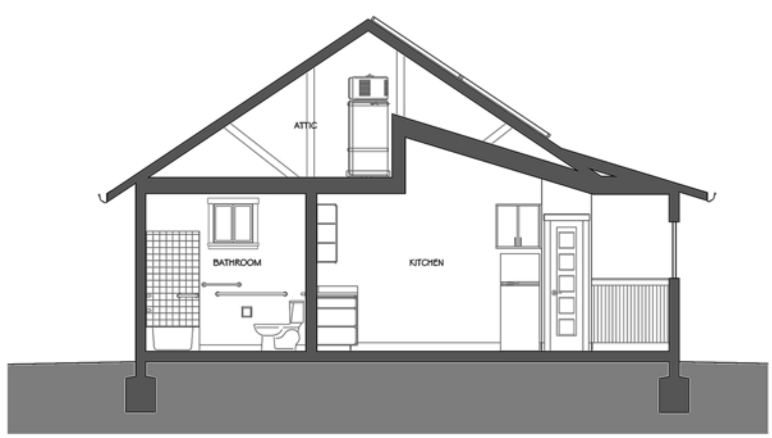
COTTAGES AT CYPRESS — FLOOR PLANS AND SECTIONS

FLOOR PLAN

STANDARD SECTIONS
ALL UNITS

0 1 2 4 8 FT





Building Envelope — Insulation and Windows

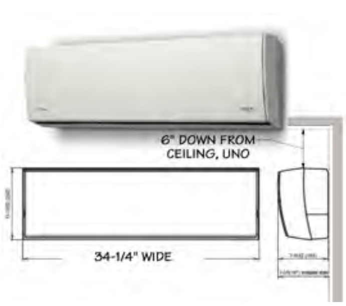
The windows are double-glazed, but do not have the low-e coatings, which are conventionally used in most climate zones of California to reduce the cooling load produced by solar gains. This location in the mild climate of the Northern California coast generally has little or no cooling load. The seasonally large heating load, on the other hand, is reduced in these houses by the passive solar heat gains that are obtained by omitting the low-e coating.

Insulation levels were designed to California energy code only, which required R-21 walls and R-35 roofs. No rigid insulation was installed on the outside of the studs to prevent solar bridging because of the cost premium, not appropriate for tightly budgeted affordable housing.

Building Envelope — Airtightness

Measures were taken to air-seal the homes and meet the requirements of the *Energy Star® for Homes* program. These included gaskets under the sill plates were as well as complete inspection and sealants in all the gaps in the enclosing structures.

Each house was tested using the Blower Door Test and every house in the final test measured 3.0 ACH50 or better, as required by *Energy Star® for Homes*.



*(Above)*Ductless mini-split heat pump unit: outdoor compressor unit *(top)* and indoor heating/cooling unit *(bottom)*.

Heating, Ventilating and Cooling Systems

The houses are heated and cooled with high-efficiency ductless mini-split heat pumps[1]. Only one mini-split wall unit is required since the cottages are small.

The mildness of the marine climate allows natural ventilation with operable windows for the entire year so no HRV units are necessary for fresh air ventilation and the heat exchange between outgoing and incoming air. Normally, they would be recommended for climate zones with larger heating and cooling loads and very airtight houses.

The kitchen fans exhaust directly to the outside and meet *Energy Star®* standards for power demand, air flow rates and sound level. Recirculating fan units were deemed to be unsatisfactory for their effect on indoor air quality.

Lighting and Plug Loads

All lighting is provided by LED sources for maximum efficiency.

Electric coil ranges were selected were specified for the kitchens for their affordability compared to electric smooth-top type. Electric induction cooktops were considered too costly for consideration despite advantages in terms of energy use.

Domestic Hot Water

Each house has a 50-gallon heat pump water heater[2]. When the energy modeling for the houses showed that domestic hot water would be a major part of the total energy use, the project team decided to specify heat pump water heaters as an energy efficiency measure. Since this type of water heater requires a comparatively large closet size and the floor plans had already been completed, the water heaters were placed in the attic space to avoid taking up some of the usable floor space.

Construction

Since the individual houses were simple in design and conventionally detailed with standard products, the construction process was straightforward.

[1] 25-SEER Fujitsu 9RLQ with a heating seasonal performance factor of 12.

[2] GE GeoSpring™ Heat Pump Water Heater

Renewable On-Site Energy Supply

The solar PV system size for each unit is designed to supply the annual energy demand of that unit's household electrical needs plus an allowance for the electrical energy required to recharge one electric vehicle driven for 5,000 miles in a year.

This design criterion resulting in the sizing of the individual systems as follows: each one-bedroom cottage is equipped with a 4 kW (DC) system and each two-bedroom cottage has a 5 kW system, for a total of 102 kW for all the houses in the development. There is also a 20 kW system for the shared buildings and their energy demand. The entire collection of small systems are independent and separately metered by the utility, then billed to the occupants.

Because two of the houses in the northwest corner of the site are in the shade of the tall cypress trees, their systems are located at the communal buildings, tied into the communal system for practical operation purposes. So the total system at the communal buildings is nominally 29 kW and the utility allocates the portion of the net-metered credit from this total system to the two units that are without any solar PV systems on the roof (units #8 and #12).

Three electric car charging stations are provided in the communal parking lot near the community center.

*(Below)*Two-bedroom.cottages with 5 kW solar PV arrays. (Photo by Ryan Filgas.)

PHOTO: RYAN FILGAS

PHOTO: RYAN FILGAS

(Left) View of a typical ZNE cottage for low-income seniors.

Energy Performance
Energy Modeling and Post-Occupancy Measurement

Energy Use—Modeling

Energy modeling was done for representative one-bedroom and two-bedroom houses in order to determine their energy use profiles and to support the application for *Low Income Housing Tax Credits (LIHTCs)*[3] essential to the project.

This modeling was done using the *California Utility Allowance Calculator (CUAC)*. The CUAC software allows energy consultants working for affordable housing developers to provide a more accurate estimate of what tenants will pay for utilities, taking into account the energy affecting features of the proposed building, the solar PV system designed for it, and the applicable tariff. (The CUAC is intended for use with new construction projects.)

The CUAC results for the annual energy use for each system for the typical one-bedroom and two-bedroom units appear in the charts on the next page.

Energy Use—Post Occupancy Measurement

The actual energy use by each house has been monitored by the solar PV system contractor using recorded data metered at the individual inverters. Since the floor plans are repetitive, the energy use of three houses were selected as representative of the individual houses of the project as a whole:

- House #18, a one-bedroom unit with the typical linear plan
- House #26, a one-bedroom unit with the typical square plan
- House #23, a two-bedroom unit with the common plan for all six

See the Landscape/Site Plan on p. 81 for the location of these houses on the site. See also the individual floor plans and sections of these houses on pp. 82-85.

The measured monthly energy use for each of these three houses during one particular year is shown in the charts on pp. 93-94. (A different year was selected for each house based on the data availability). For comparison with the CUAC modeling results for a house of the same type, the CUAC-modeled monthly energy use predicted for the same month is integrated with the measured energy use in these charts.

The modeled and measured energy use are remarkably close, except in certain months in the summer. The differences during those periods may be attributed the occupants natural frugality with the cooling operation or perhaps simply periods of non-occupancy for a variety of reasons.

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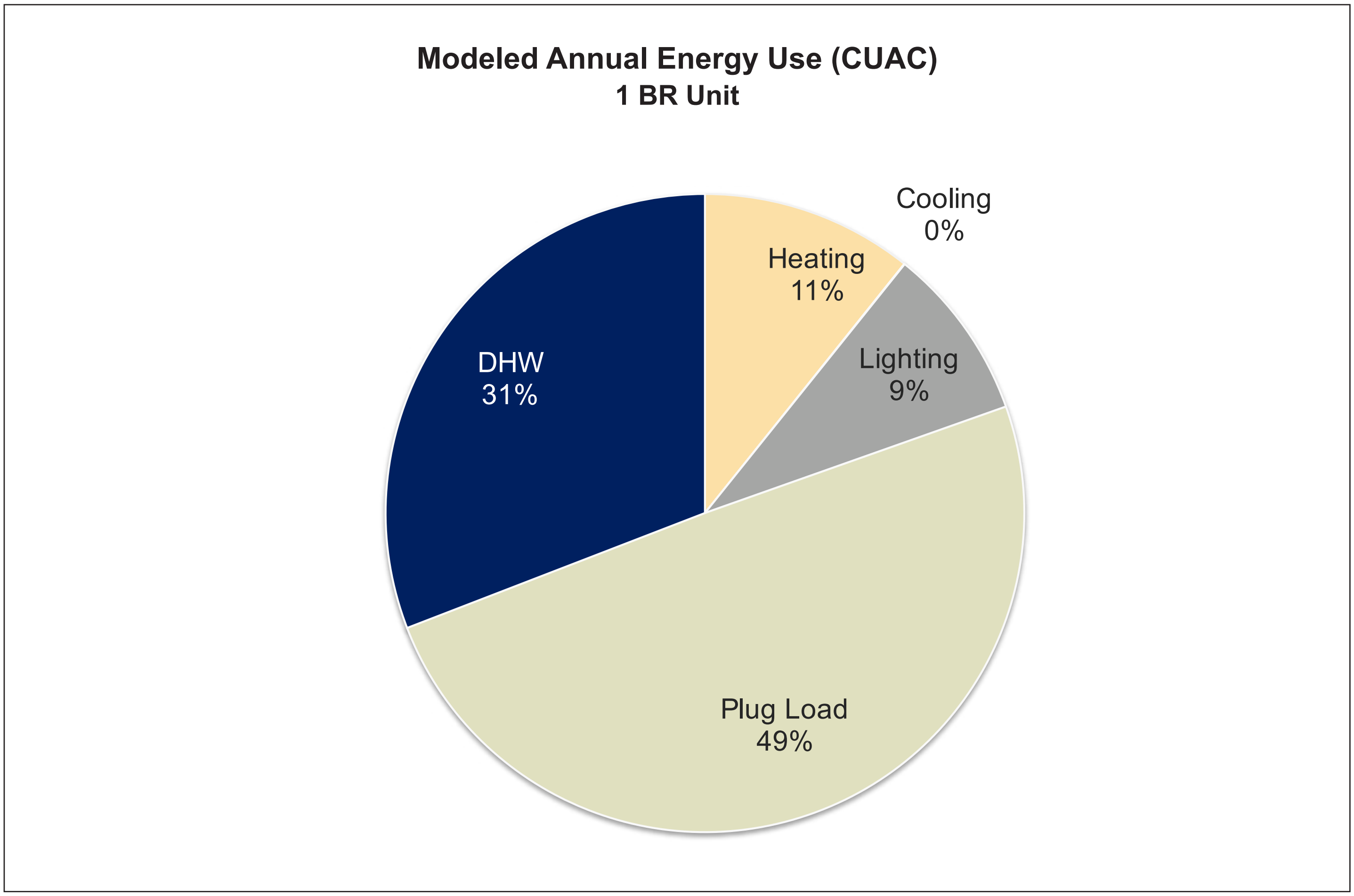
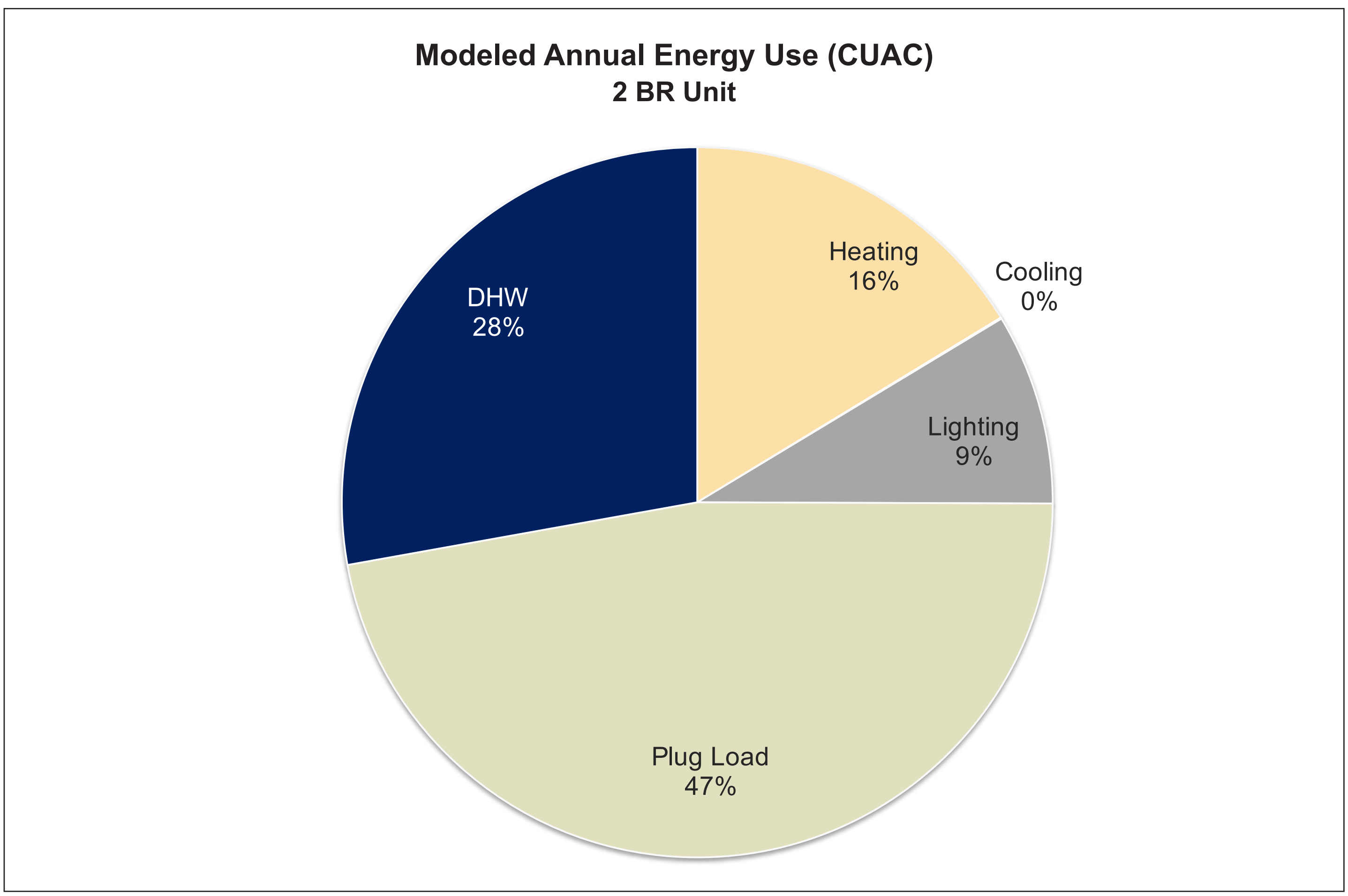
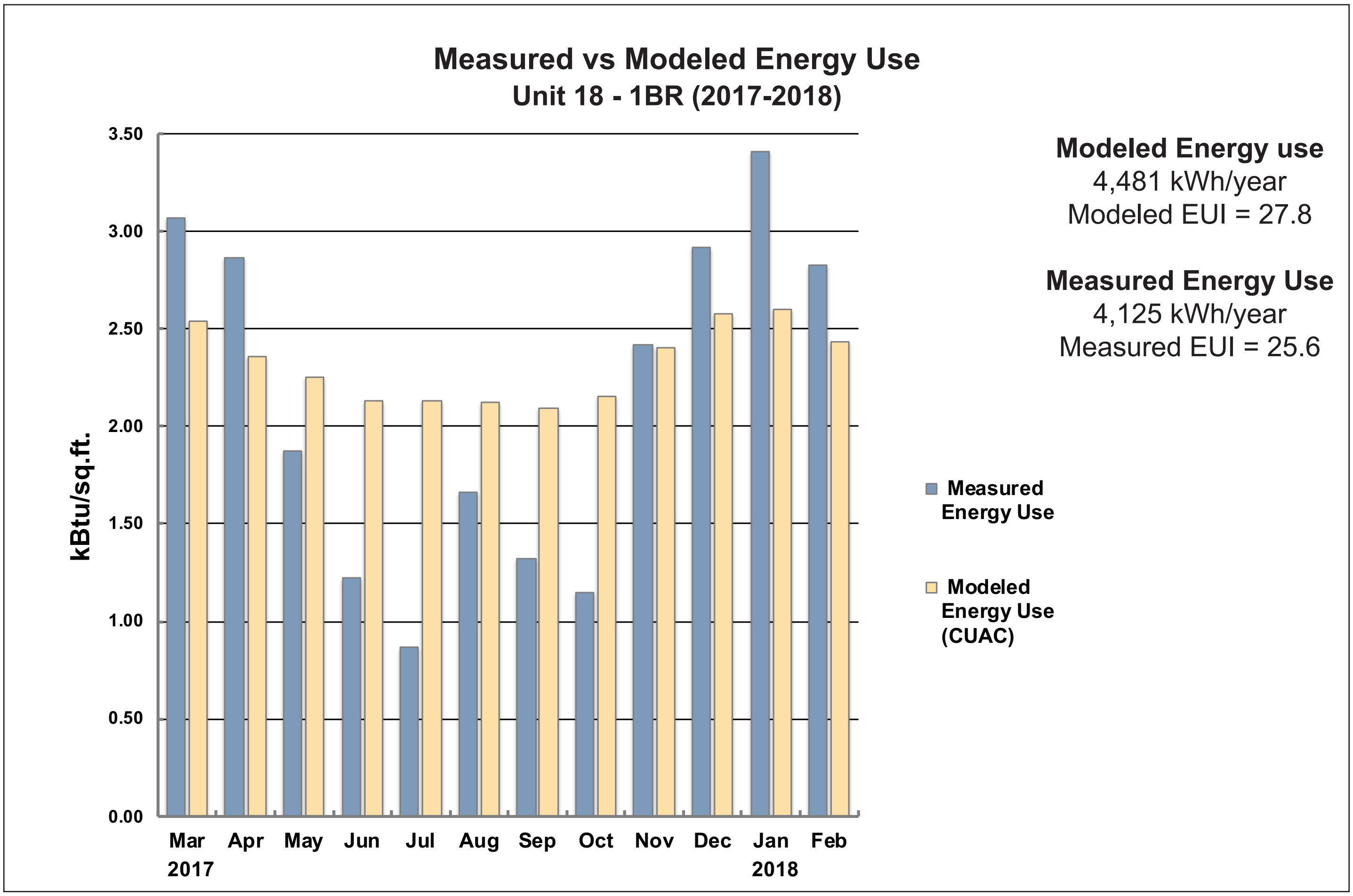
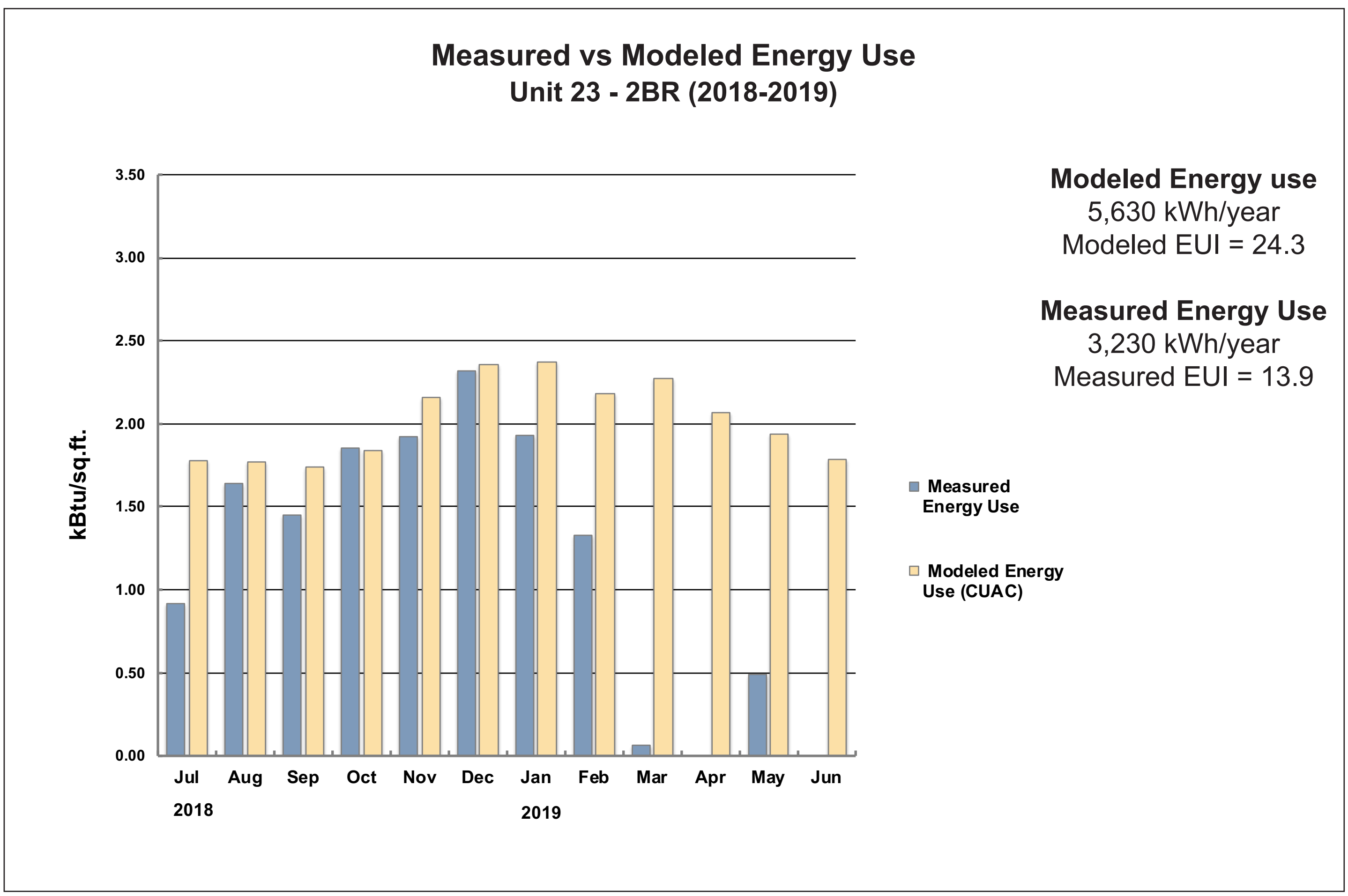
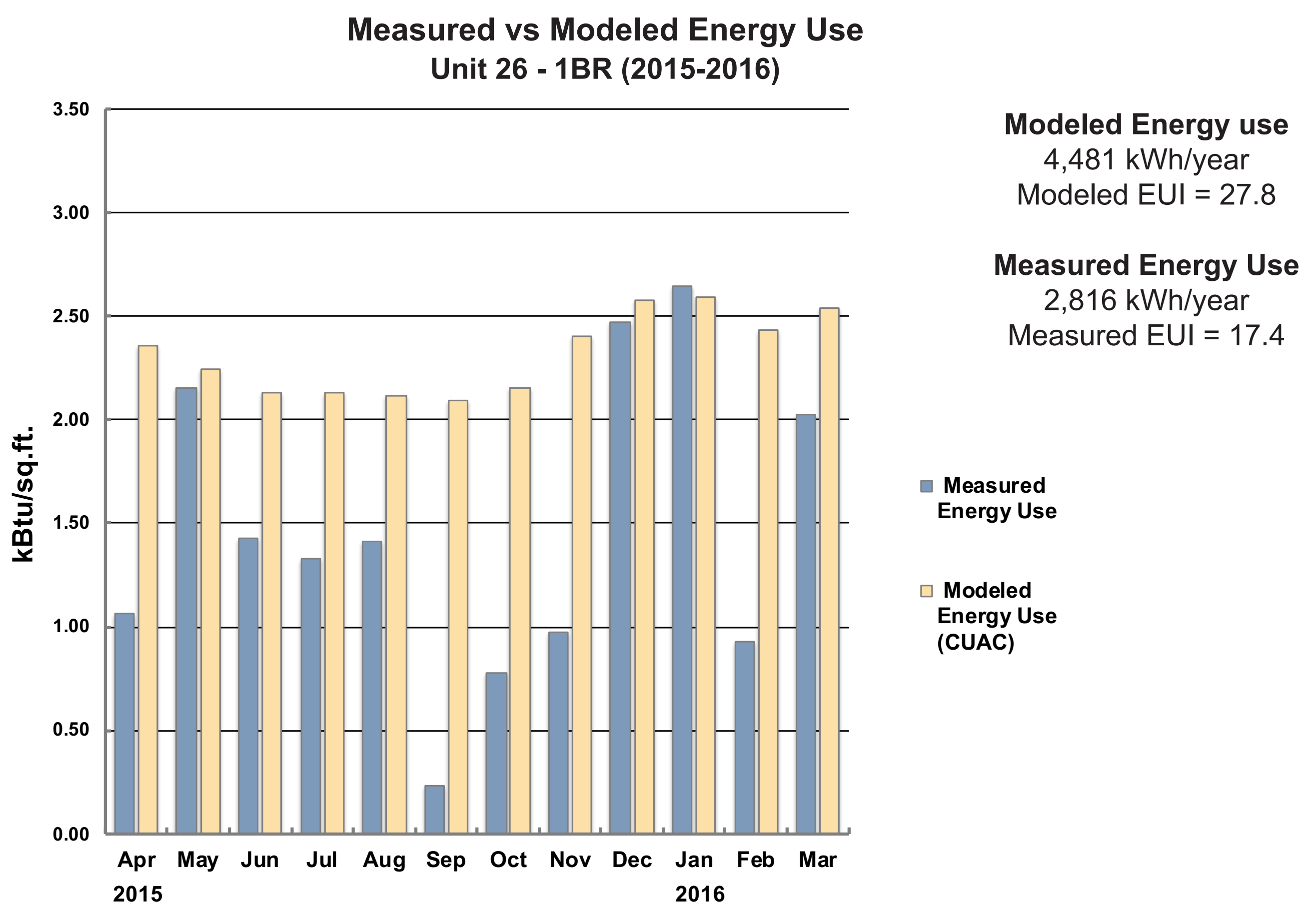
[3] The California Tax Credit Allocation Committee (TCAC) is the state agency that allocates these federal and state tax credits in support of affordable housing. Applicants for LIHTCs must estimate the monthly income and expenses for proposed projects. As part of the calculation, applicants need to provide an estimate of the utility costs tenants will face. Historically, the most common source of the utility cost estimate was local public housing authorities' utility allowance schedules. Those schedules generally overestimate what tenants' utility costs will be. In 2008, the California Energy Commission worked with the affordable housing community and TCAC to create a more accurate tool for estimating tenants' utility costs: the *California Utility Allowance Calculator, or CUAC*.


Modeled Annual Energy Use (CUAC)
1 BR Unit
Cooling 0%
Heating 11%
Lighting 9%
DHW 31%
Plug Load 49%


Modeled Annual Energy Use (CUAC)
2 BR Unit
Heating 16%
Cooling 0%
DHW 28%
Lighting 9%
Plug Load 47%


Measured vs Modeled Energy Use
Unit 18 - 1BR (2017-2018)
kBtu/sq.ft.
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb
2017
2018
Modeled Energy use
4,481 kWh/year
Modeled EUI = 27.8
Measured Energy Use
4,125 kWh/year
Measured EUI = 25.6
Measured Energy Use
Modeled Energy Use (CUAC)


Measured vs Modeled Energy Use
Unit 23 - 2BR (2018-2019)
kBtu/sq.ft.
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
2018
2019
Modeled Energy use
5,630 kWh/year
Modeled EUI = 24.3
Measured Energy Use
3,230 kWh/year
Measured EUI = 13.9
Measured Energy Use
Modeled Energy Use (CUAC)



Energy Production versus Energy Use: Zero Net Energy Performance

The charts on pp. 95-97 show the solar PV systems' energy production during the same periods of use for the three houses. It is clear from these representative performance charts that the systems are providing more energy than is used in the houses.

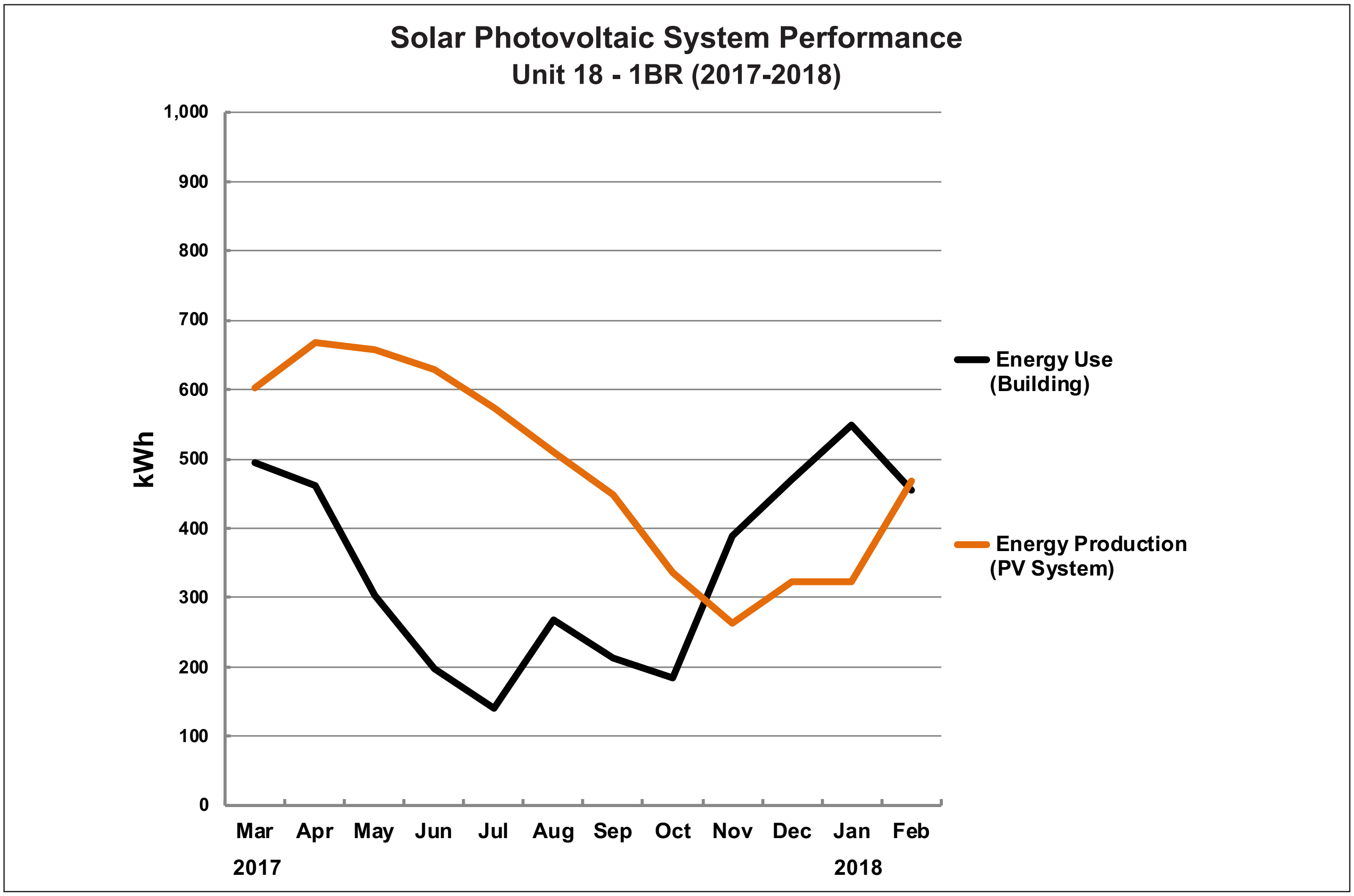
Similarly, when the *cumulative energy production*[4] for each house is charted from this data, the houses can be seen to be strongly *net positive* performers. Since these three houses are representative of all the houses in the project, the entire project is clearly achieving an energy performance greater than ZNE.

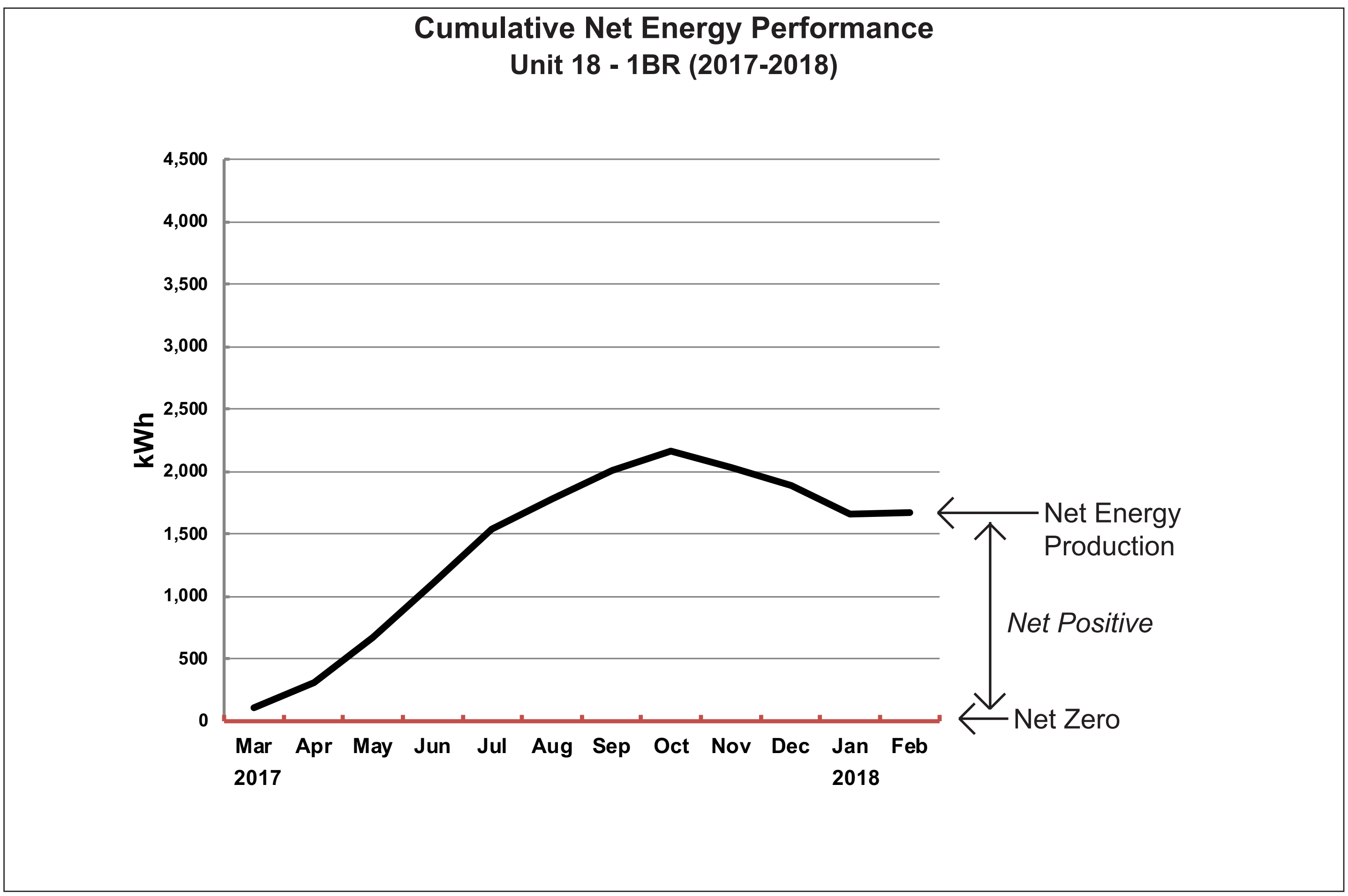
Post-Occupancy: Observations and Conclusions

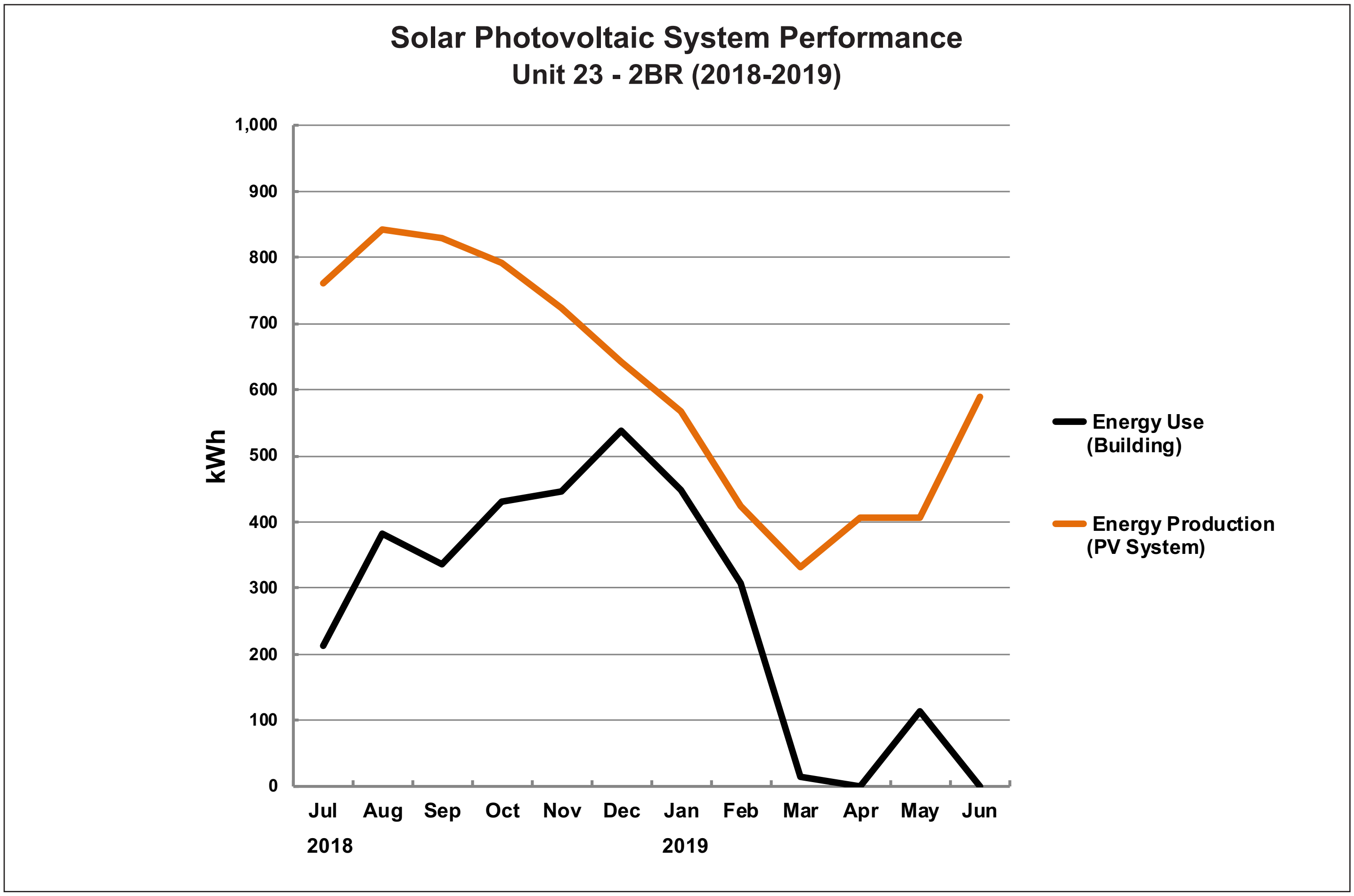
The City of Fort Bragg, the developer and design team and, most importantly, the resident seniors occupying the houses expressed great satisfaction with all aspects of the project when interviewed for this case study. The occupants particularly noted how happy they were to receive a check from the utility rather than a bill, especially since they were on a fixed income. In addition, they were thermally comfortable at all times and were not required to consider reductions because of a high utility bill.

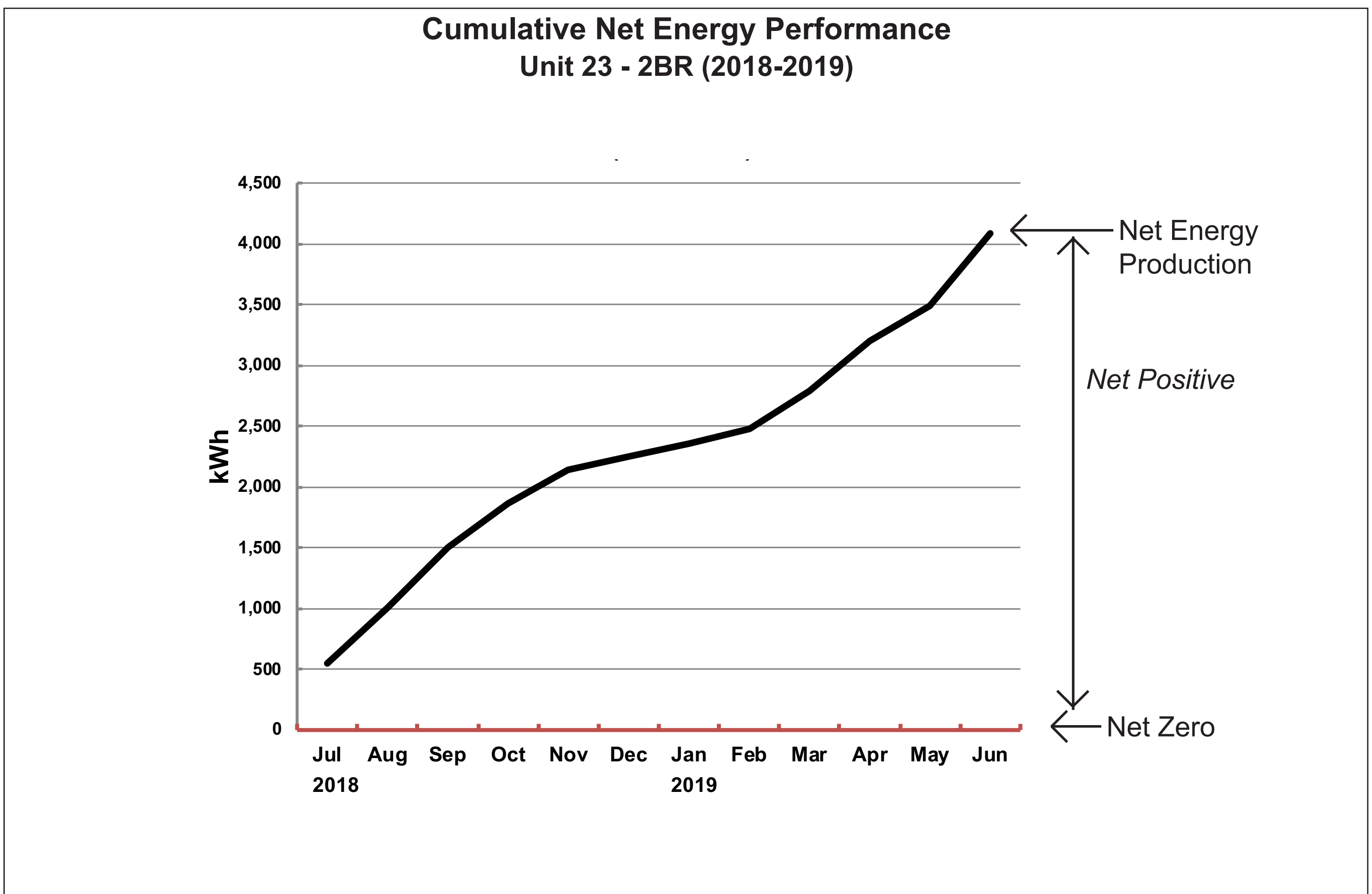
The project team described only one aspect of the design that would be done differently in a future project: the location of the heat pump water heater in the attic space. This location has several practical drawbacks. The primary one is that the heavy vertical tank is overhead rather than at the floor level, a concern in the event of an earthquake. Another is the relative difficulty of access for service or adjustment of control settings.

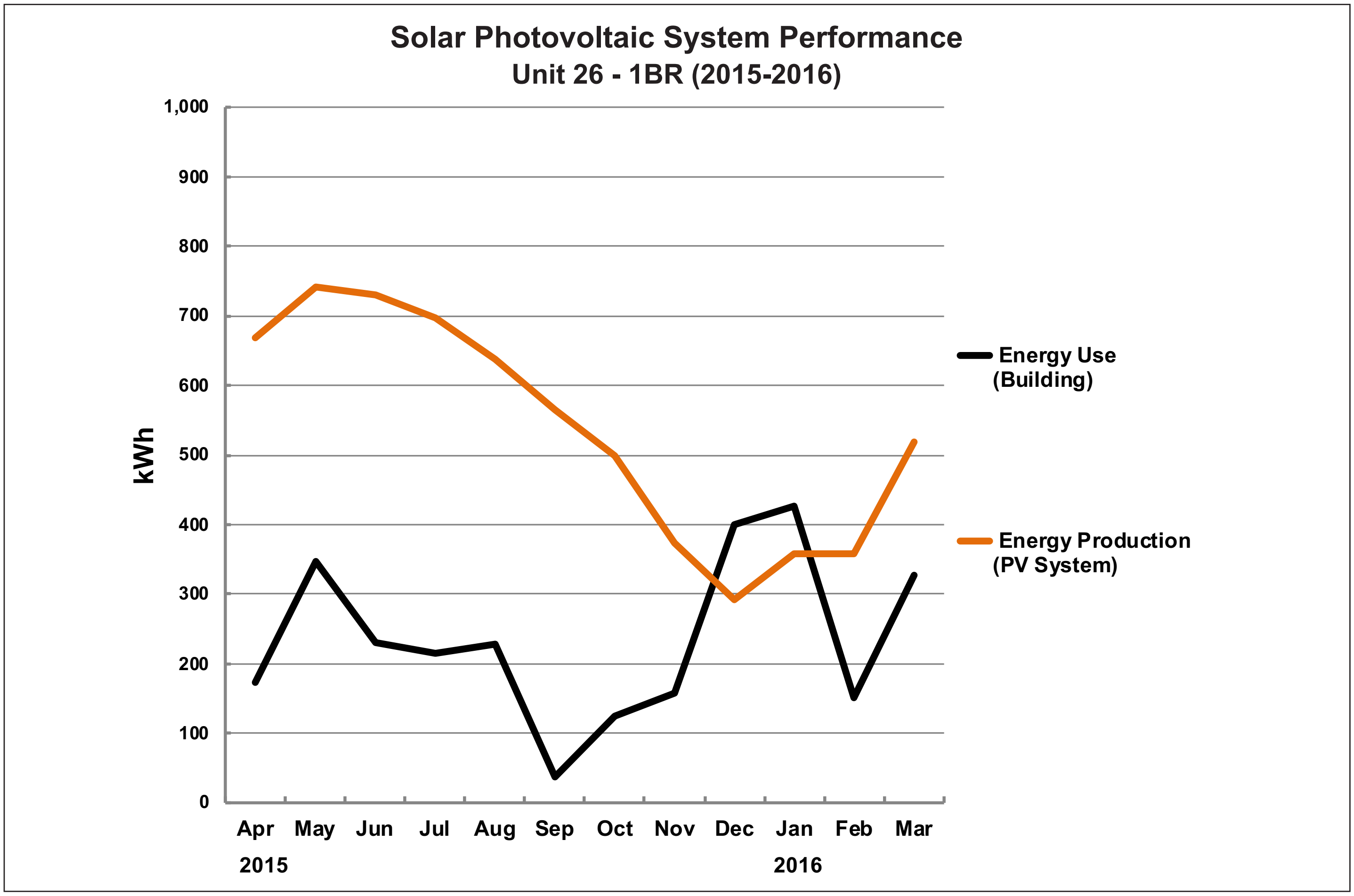
[4] The *cumulative net energy production* is a chart that essentially shows the progression of the energy performance toward ZNE by adding each month's net energy performance to the previous month's total—if, at the end of the 12-month period, the curve remains on the positive side of the zero axis, then the building in indeed performing better than ZNE, i.e., *Net Positive*.

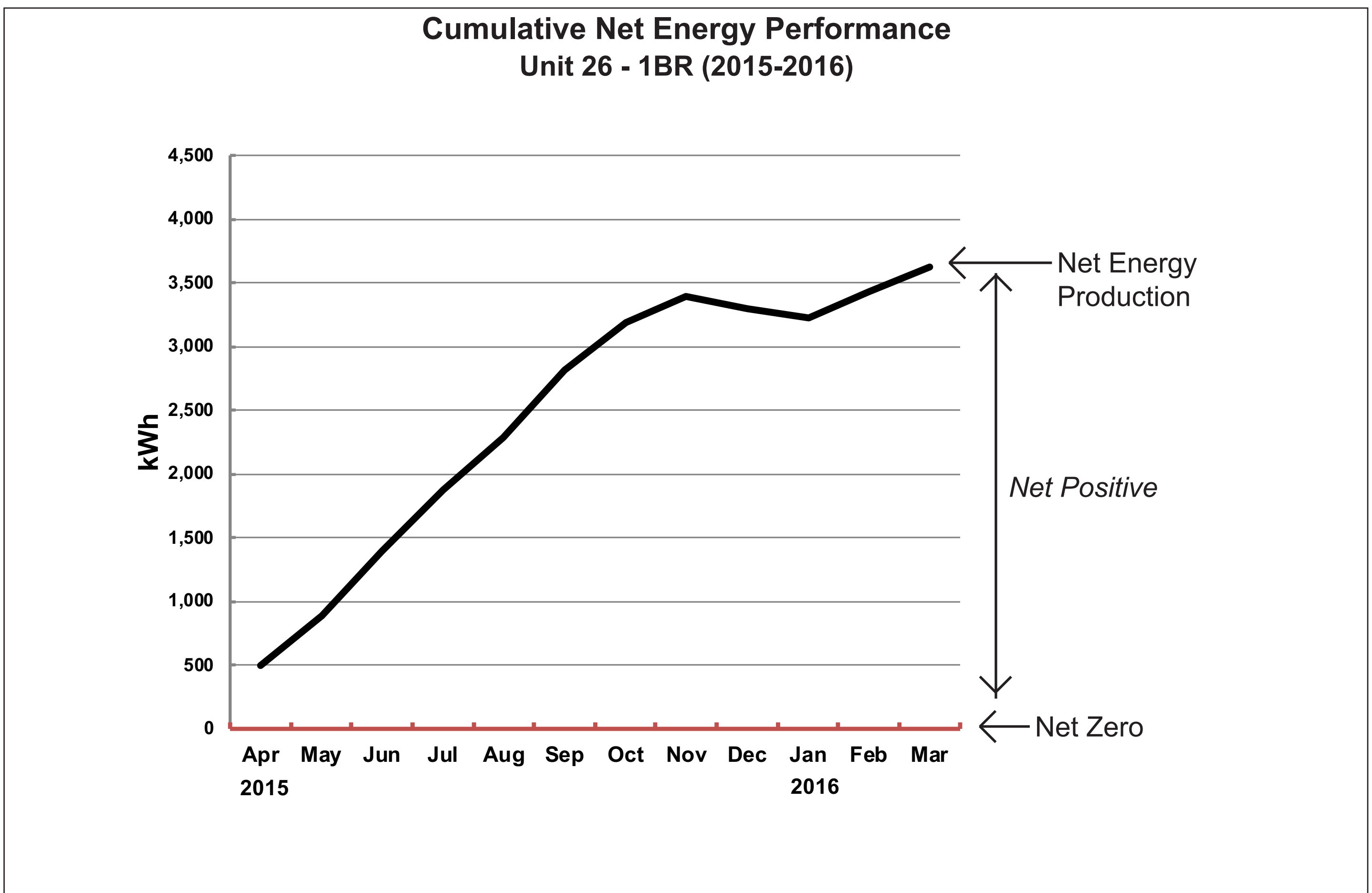

Solar Photovoltaic System Performance
Unit 18 - 1BR (2017-2018)
kWh
1,000
900
800
700
600
500
400
300
200
100
0
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
2017
2018
Energy Use (Building)
Energy Production (PV System)


Cumulative Net Energy Performance
Unit 18 - 1BR (2017-2018)
kWh
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
2017
2018
Net Energy Production
Net Positive
Net Zero


Solar Photovoltaic System Performance
Unit 23 - 2BR (2018-2019)
kWh
1,000
900
800
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
2018
2019
Energy Use (Building)
Energy Production (PV System)


Cumulative Net Energy Performance
Unit 23 - 2BR (2018-2019)
kWh
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
2018
2019
Net Energy Production
Net Positive
Net Zero


Solar Photovoltaic System Performance
Unit 26 - 1BR (2015-2016)
kWh
1,000
900
800
700
600
500
400
300
200
100
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
2015
2016
Energy Use (Building)
Energy Production (PV System)


Cumulative Net Energy Performance
Unit 26 - 1BR (2015-2016)
kWh
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
2015
2016
Net Energy Production
Net Positive
Net Zero